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Design and Implementation of Versatile Delivery Robot †

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Abstract: This paper focuses on the design and implementation of a versatile delivery robot which integrates a secure locking system, GPS navigation, customer authentication, and a camera system for real-time monitoring. The advanced locking system ensures the protection of delivered goods during transit, addressing security concerns. GPS navigation optimizes routes for efficient last-mile deliveries, reducing overall delivery times. Customer authentication adds an extra layer of security, allowing only the designated customer, equipped with a unique authentication method, to unlock and retrieve their parcel. The integrated camera system provides continuous monitoring throughout the delivery process. The combination of these features showcases technological innovation and also addresses critical aspects of security and customer trust in autonomous deliveries. The successful integration of these features positions the delivery robot as a reliable and customer-friendly solution for the evolving landscape of last-mile logistics.

Keywords: navigation; authentication; last-mile logistics; obstacles; detection; efficiency

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1. Introduction

A robot navigates using just an RGB-D camera and a single-board computer, combining rule-based and learning-based methods to avoid collisions and reach its destination in real-time. [1]. Smart robots employ deep reinforcement learning to collaboratively navigate dynamic 3D environments, utilizing the Island Policy Optimization model to efficiently track and pursue multiple targets simultaneously [2]. And navigation can be carried out on its own using a smart learning system. This system uses a modular deep-Q-network architecture and learns everything in a 3D simulator this is called zero-shot transfer which has adaptability and the ability to avoid collisions [3]. Dynamic Waypoint Navigation (DWN) enables robots to intelligently plan paths in human environments, selecting waypoints dynamically to navigate efficiently and safely while considering varying speeds and routes [4]. OABot is a helpful service robot with a smart communication system. This robot tackles problems like figuring out where it is, moving around safely and planning the best route to its destination [5,6]. Robots adaptively plan paths amidst changing environments using classical and heuristic methods, refining their ability to adjust plans based on the pace of surrounding movements [7]. A self-learning system for wheeled robots that uses both regular and depth-based camera information, along with real-time traction data, allows these robots to navigate outdoor spaces autonomously [8]. This self-learning method combines both what the robot sees and hears by integrating audio and visual features [9]. making rescue robots more independent and effective in saving lives. The HiDO-MPC method takes a smart approach, using a structured system [10].

Research reveals a gap in navigation and delivery techniques, emphasizing the need for simplicity and versatility, particularly in adapting to changing environments. The essence of an environment changing lies in its dynamic adaptability, which is crucial for effective navigation and delivery systems. Our study focuses on developing a robot capable of adapting to weather changes while efficiently executing delivery tasks. The integration of a connected camera enables the robot to monitor and respond to its surroundings, facilitating easy path management through a mobile interface. This adaptive nature ensures user-friendly and flexible navigation for effective delivery operations.

2. Methodology

In this section explains the design of the robot and its navigation system is detailed. In this camera module is incorporated for observing the movement of the robot, with Arduino serving as the microcontroller and motor drivers and sensors are integrated into the system to facilitate precise control and navigation which is important for movement of the robot (Figure 1).

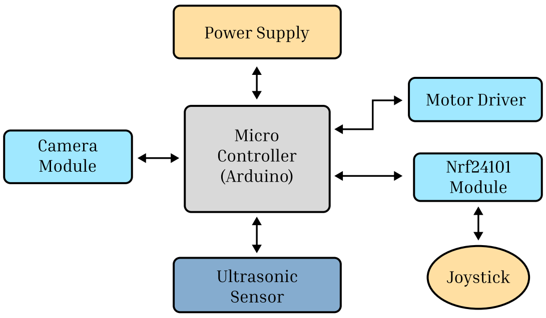

Figure 1. Block diagram of versatile delivery robot.

3. Design of the Delivery Robot

The delivery robot design maximizes efficiency and accessibility, featuring sturdy wheels for versatile terrain navigation. A microcontroller circuit serves as the central neural hub, coordinating communication and core component functions (Table 1). A strategically positioned battery ensures sustained operation, directly impacting range and reliability. Atop the robot, a camera provides a comprehensive view for real-time monitoring and navigation assistance.

Table 1. Specifications of versatile delivery robot.

Components	Specifications
1.Arduino Uno	ATmega 329
2. Nrf24l01 Module	Range of 500 to 800 meters
3. Buzzer	Digital Signal to Sound
4. Relay	12v Operation Voltage
5. Servo	180 Degree Rotation
6. L293d Motor Driver IC	Motor Control using Signal
7. Esp32 Cam	802.11b/g/n Wi-Fi, and Low-Power CPU
8. 12v Power Supply	Input Power
9. Ultrasonic Sensor	Range of 10 meters

An open lid facilitates easy loading and unloading of products, emphasizing user-friendly access. Ultrasonic sensors and LEDs strategically integrated on the frontal section enhance perceptual capabilities and aid in obstacle detection. Ultrasonic sensors act as the robot's eyes, detecting obstacles and enabling safe navigation. LEDs serve as visual indicators, signaling operational status and enhancing communication with operators and bystanders. This combination enhances safety and user-friendly interaction with the environment. The integration underscores a holistic approach prioritizing functionality and effective communication (Figure 2).

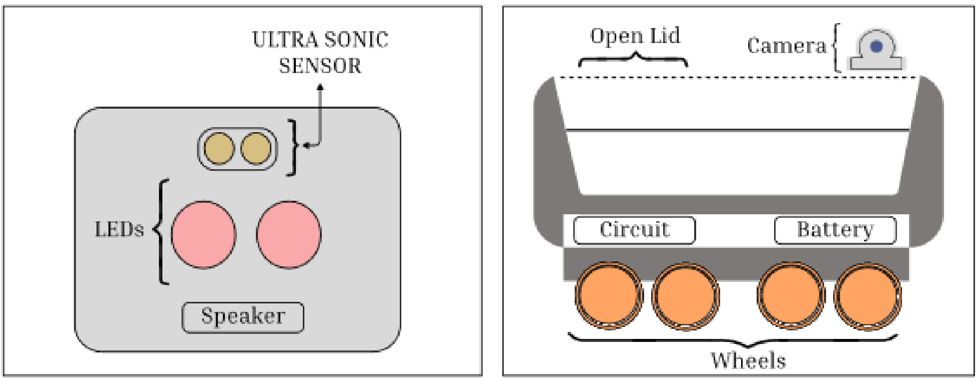

Figure 2. Front and side view of delivery robot.

The motors provide traction force in the area where the driven wheels' tires and the road surface come into contact to propel the vehicle forward. This endeavor ought to surpass the overall resistive force F_{total}, which is entirely ascertained by a four-dimensional

$$\mathrm{F_{total}} = \mathrm{F_a} + \mathrm{F_r} + \mathrm{F_c} + \mathrm{F_d}$$

where F_a is force, F_r is rolling resistance force, F_c is moving force, and F_d is additional disturbance.

The motion of the delivery robot is influenced by factors like shape, size, velocity, and air density.

$$Fa = \frac{1}{2}pC_dA_fv^2$$

where, P is the density of air, C_d is the drag coefficient, A_f is the area of the vehicle front; v is the vehicle speed.

The rolling resistance force, also known as wheel friction, arises from the deformation of the wheels and the road surfaces. Factors such as tire types, pressure, temperature, speed of the Battery Electric Vehicle (BEV), and thread thickness influence the level of wheel friction. This force can be expressed as follows:

$$F_r = {}_rM_vgcos\alpha$$

where, M_v is the vehicle mass, α is the road gradient, and μ_r is the dimensionless wheel friction factor

The gravitational force significantly influences the following aspects of the vehicle's behavior:

$$F_c = M_vgsin\alpha$$

Estimation of Power and Torque

Regarding the backward-facing orientation of the robot model, it precisely follows the speed profile, and power consumption is determined accordingly. The traction power required for the robot's driving speed is calculated as follows:

$$P_{trac}(t) = M_vv(t)\frac{dv(t)}{dt}P_{res}(t)$$

where the resistant power P_{res} is:

$$P_{res}(t) = F_{res}t(v)$$

$$P_{res}(t) = ({}_rM_vgcos\alpha + \frac{1}{2}pC_dA_fv^2 + M_vgsin\alpha)\text{v}$$

And the acceleration $\frac{dv(t)}{d(t)}$ is the derivative method of the backward calculation difference:

$$a(t) = \frac{dv(t)}{d(t)} = \frac{v_t - v_{t-1}}{\Delta t}$$

When the EM is used in-wheel, in the wheel, its inertia is introduced to the wheels' wheel inertia and tires' tire inertia (I_{wh}). Considering the instant of inertia at the wheels throughout traction, the strength at the wheels stage becomes

$$P_{\omega h}(t) = P_{trac}(t) + J_{\omega h}.\omega_{\omega h}.\omega_{\omega h}$$

$$\omega_h = \frac{V_t}{r}$$

$$J_{\omega h} = \frac{1}{2}4(m_{\omega h} + m_{EM})r^2$$

4. Result

The development of the navigation and delivery robot presented in this study revolves around the integration of various components to create a versatile and adaptive system capable of efficiently navigating different environments while executing delivery tasks effectively (Figure 3). The design and implementation of the robot encompass several key aspects, including its physical structure, navigation system, wireless connectivity, obstacle detection capabilities, and remote-control interface. Alternatively, users can operate the delivery robot remotely through a web application accessed via its IP address. The web application serves as a user-friendly interface for controlling the robot's navigation and delivery tasks from any internet-enabled device, such as a smartphone, tablet, or computer. Through the web application, users can monitor the robot's location, route, and progress in real-time, as well as send commands for navigation and task execution. This remote-control capability enhances the robot's versatility and usability, enabling operators to manage delivery operations efficiently from any location (Figure 4).

Figure 3. Delivery robot.

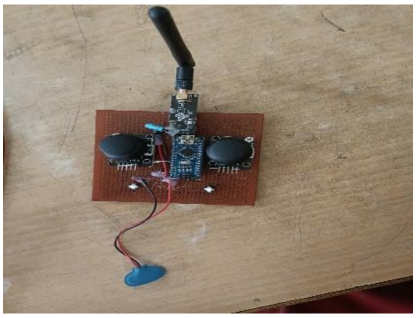

Figure 4. Joystick controller.

5. Conclusions

In conclusion, the delivery robot project represents a pioneering leap forward in modern delivery logistics, offering a comprehensive solution with user-friendly design principles. This innovative robot not only excels in efficiently navigating diverse terrains to ensure timely delivery of goods but also prioritizes user accessibility and safety. By combining sturdy construction with advanced features like real-time monitoring cameras intuitive indicators and security locking, the robot ensures a smooth and secure delivery experience for both operators and recipients. Its proactive approach to obstacle detection and communication fosters trust and cooperation, enhancing overall efficiency and reliability. In essence, the delivery robot project redefines the standards of automated delivery systems, offering a highly efficient and user-centric solution that addresses the evolving needs of modern logistics, with its blend of enhanced efficiency and customer satisfaction in the delivery industry.

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References

1. Kim, T.; Lim, S.; Shin, G.; Sim, G.; Yun, D. An Open-Source Low-Cost Mobile Robot System with an RGB-D Camera and Efficient Real-Time Navigation Algorithm. *IEEE Access* **2022**, *10*, 127871–127881. [CrossRef]
2. Qamar, S.; Khan, S.H.; Arshad, M.A.; Qamar, M.; Gwak, J.; Khan, A. Autonomous Drone Swarm Navigation and Multitarget Tracking with Island Policy-Based Optimization Framework. *IEEE Access* **2022**, *10*, 91073–91091. [CrossRef]
3. Doukhi, O.; Lee, D.J. Deep Reinforcement Learning for Autonomous Map-Less Navigation of a Flying Robot. *IEEE Access* **2022**, *10*, 82964–82976. [CrossRef]
4. Kamezaki, M.; Kobayashi, A.; Kono, R.; Hirayama, M.; Sugano, S. Dynamic Waypoint Navigation: Model-Based Adaptive Trajectory Planner for Human-Symbiotic Mobile Robots. *IEEE Access* **2021**, *10*, 81546–81555. [CrossRef]
5. Diddeniya, I.; Wanniarachchi, I.; Gunasinghe, H.; Premachandra, C.; Kawanaka, H. Human-Robot Communication System for an Isolated Environment. *IEEE Access* **2021**, *10*, 63258–63269. [CrossRef]
6. Lee, J.; Park, G.; Cho, I.; Kang, K.; Pyo, D.; Cho, S.; Cho, M.; Chung, W. ODS-Bot: Mobile Robot Navigation for Outdoor Delivery Services. *IEEE Access* **2021**, *10*, 107250–107258. [CrossRef]
7. Hewawasam, H.S.; Ibrahim, M.Y.; Appuhamillage, G.K. Past, Present and Future of Path-Planning Algorithms for Mobile Robot Navigation in Dynamic Environments. *IEEE Open J. Ind. Electron. Soc.* **2022**, *3*, 353–365. [CrossRef]
8. Gasparino, M.V.; Sivakumar, A.N.; Liu, Y.; Velasquez, A.E.B.; Higuti, V.A.H.; Rogers, J.; Tran, H.; Chowdhary, G. WayFAST: Navigation with Predictive Traversability in the Field. *IEEE Robot. Autom. Lett.* **2022**, *7*, 10651–10658. [CrossRef]
9. Kurobe, A.; Nakajima, Y.; Kitani, K.; Saito, H. Audio-Visual Self-Supervised Terrain Type Recognition for Ground Mobile Platforms. *IEEE Access* **2021**, *9*, 29970–29979. [CrossRef]
10. Saputra, R.P.; Rakicevic, N.; Chappell, D.; Wang, K.; Kormushev, P. Hierarchical Decomposed-Objective Model Predictive Control for Autonomous Casualty Extraction. *IEEE Access* **2021**, *9*, 39656–39679. [CrossRef]